Scrubbing Test in Proton Run 2009

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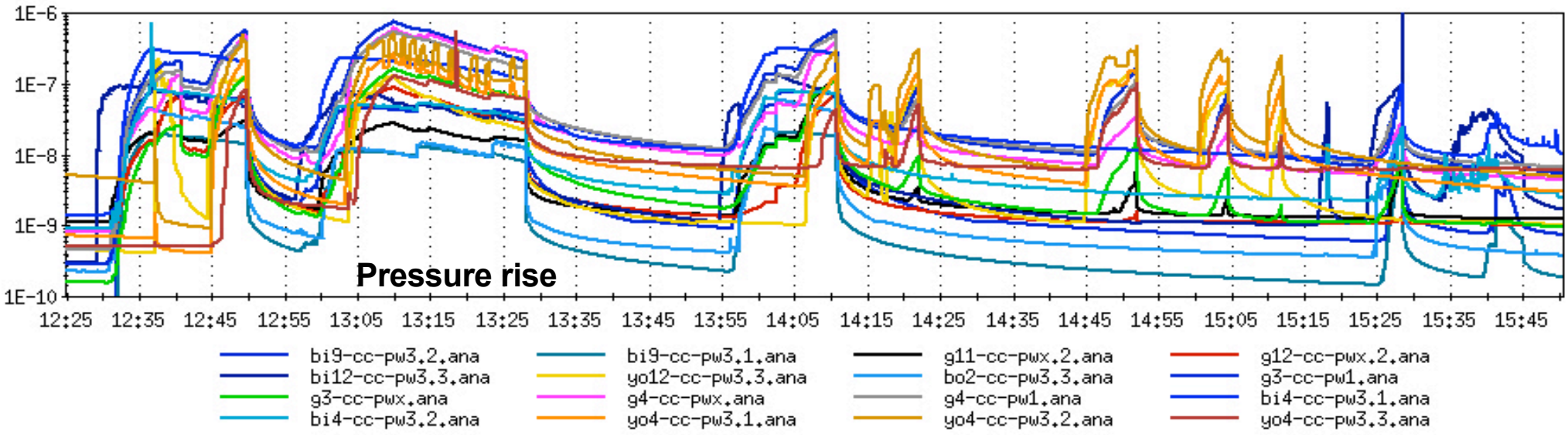
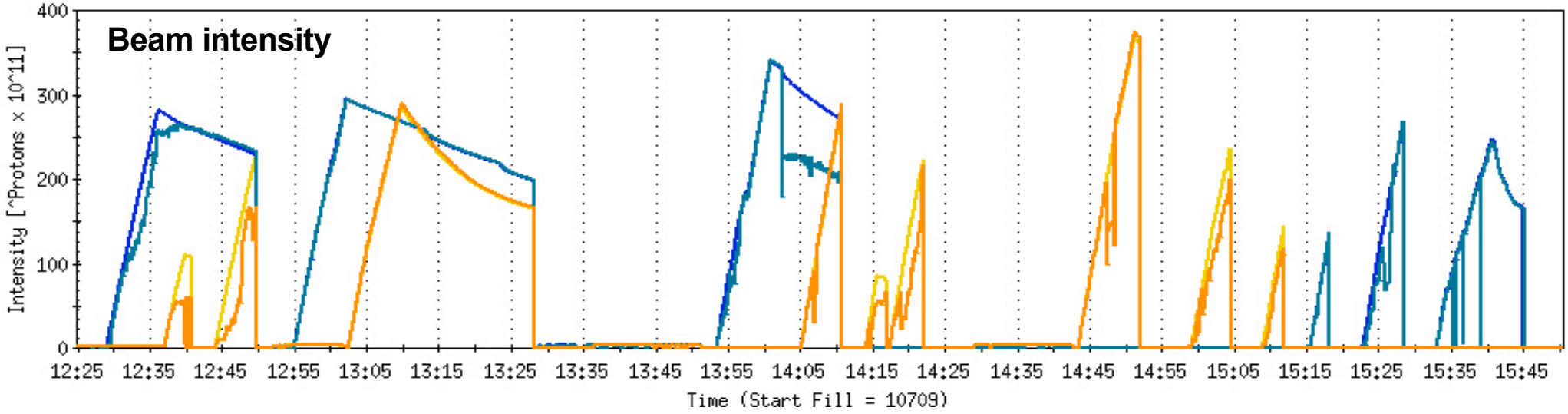
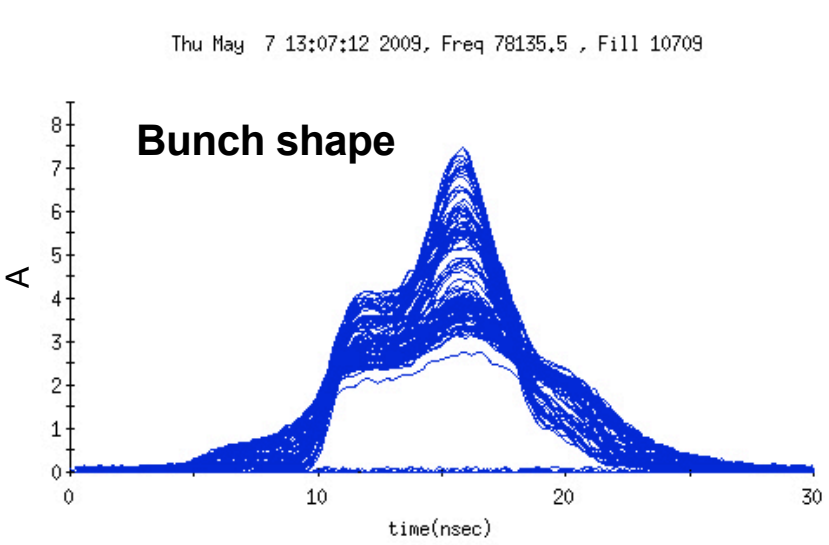
- In the proton run 2009, a beam scrubbing is tested to mitigate the electron cloud, and hence to raise the luminosity limit: 111 bunches with 3e11 to 4e11 protons per bunch are injected into RHIC. AGS quad pumping is on, the RF voltage is raised later to make shorter bunches.
- Total 8 fills with 4e11 per bunch at the injection were approved with the precaution procedure for, e.g., snakes.
- Report on the scrubbing test, Fill 10709, May 7, 2009:
  1. Beams and pressure rise.
  2. Bunch shape and fill pattern.
  3. Electron multipacting and tune shift.
  4. Scrubbing effect and memory.
  5. IPM observation and corrections.
  6. RF cavity trip-off, due to pressure rise?
  7. Cold region pressure rise.
  8. Heat load.
- Summary and conclusion

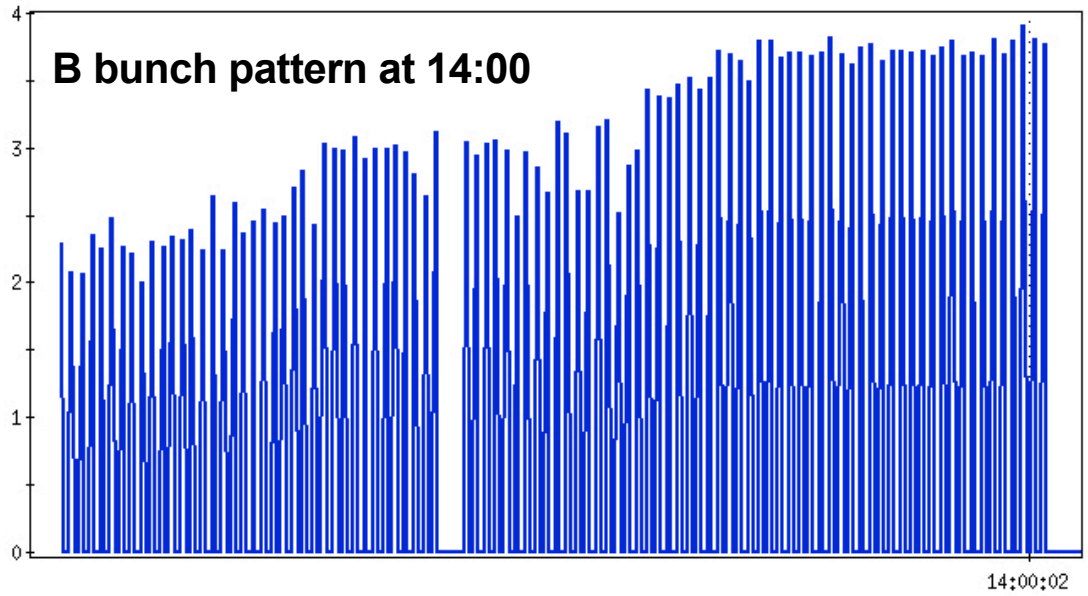


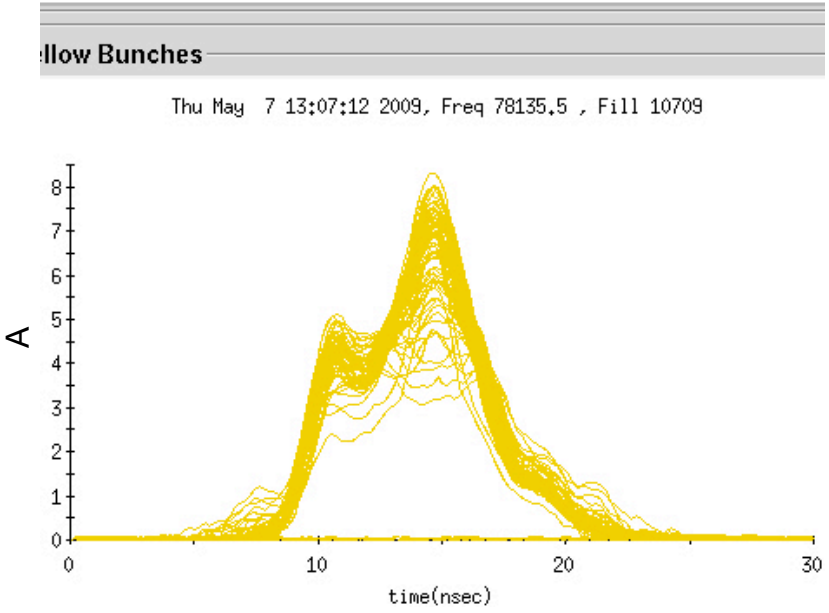


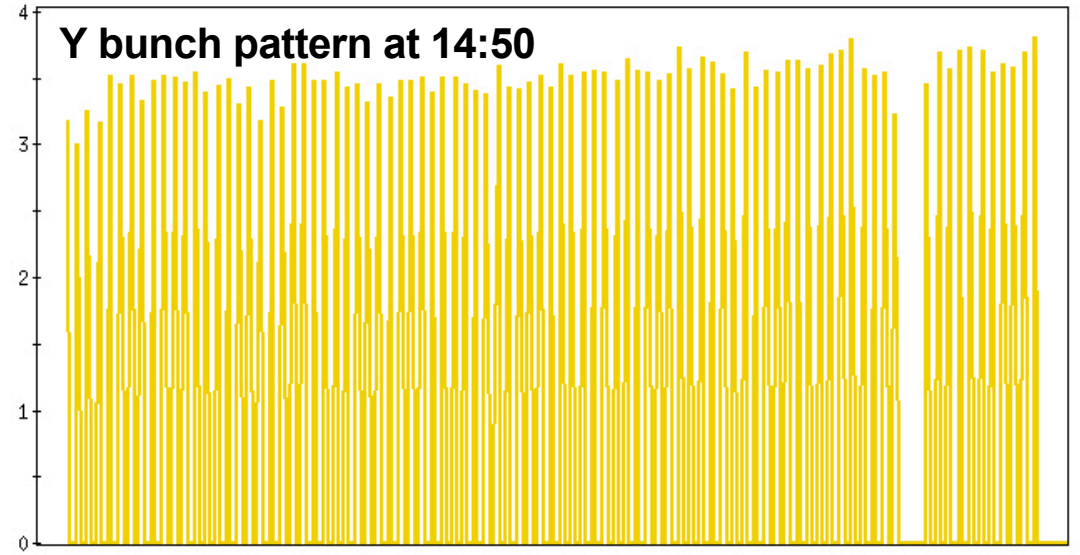
1. Beams and pressure rise

- In about 3 hours, bunches of 3e11 and later 4e11 protons, with AGS quad pumping, were injected into RHIC. Highest intensity is 341e11 in Blue and 374e11 in Yellow.
- Highest pressure rise is a little lower than 1e-6 Torr in Blue, Yellow, and Green.
- Debunching is a problem.



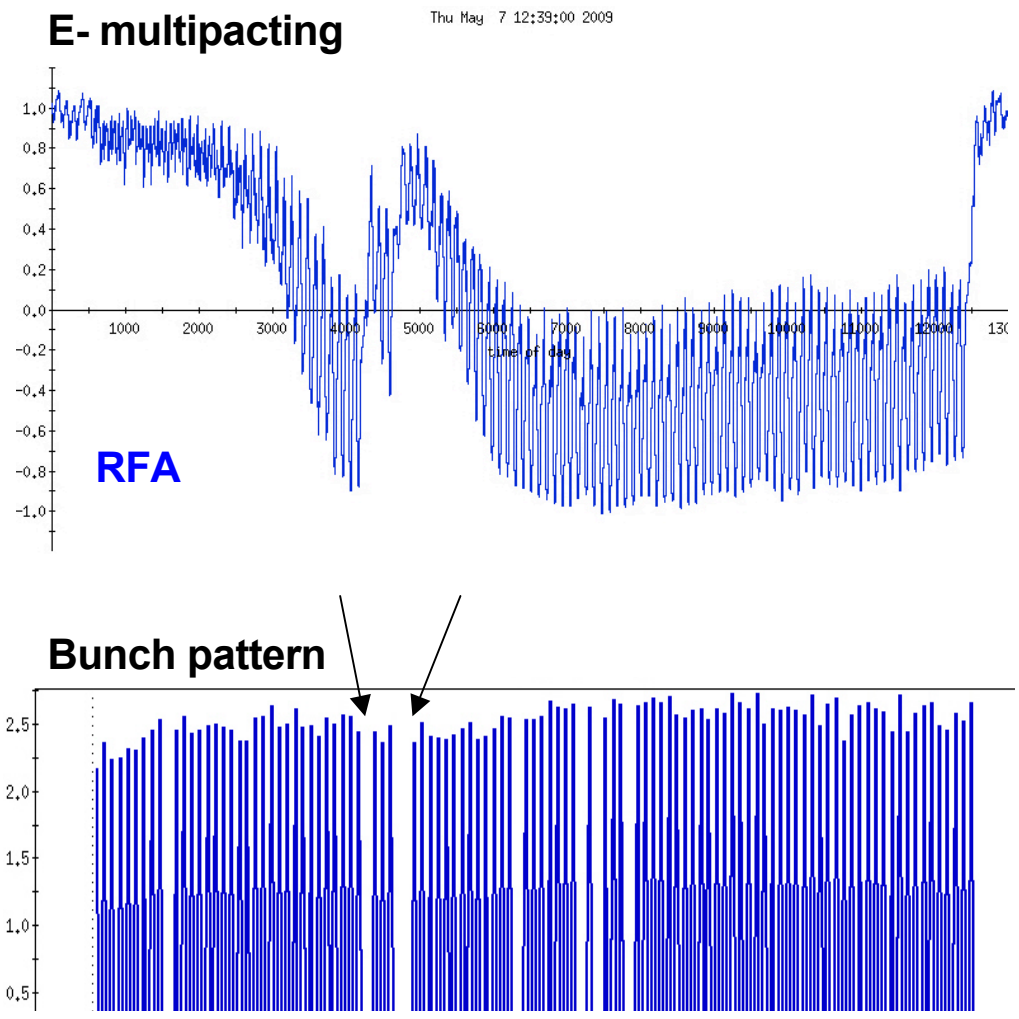


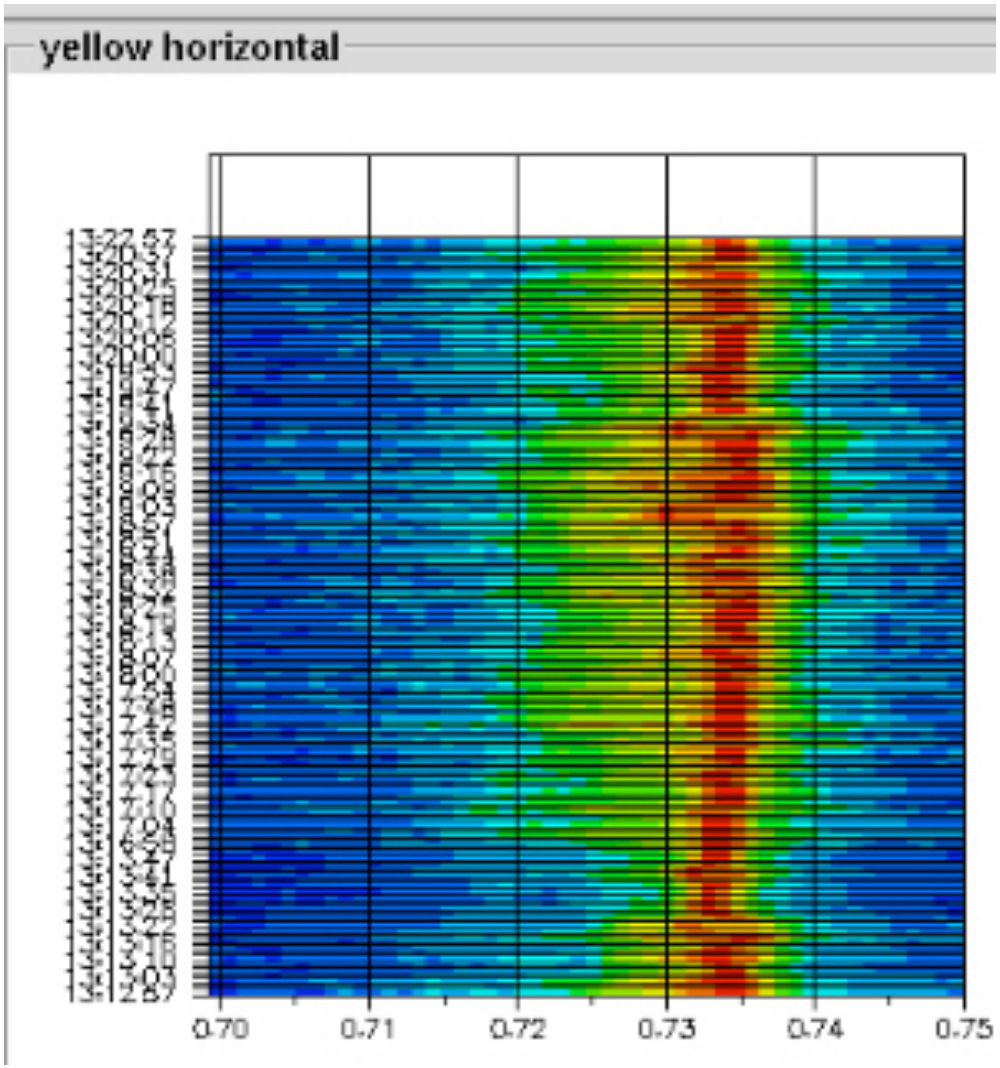




2. Bunch shape and fill pattern

- Bunch shapes at 13:07, 3e11 per bunch, with AGS quad pumping, peak current > 8 A. Normal operations is 3 A to 3.5 A.
- Blue bunch pattern at 14:00 and Yellow at 14:50, both with the highest total intensity.
- The bunch pattern might be affected by electron cloud and coherence.

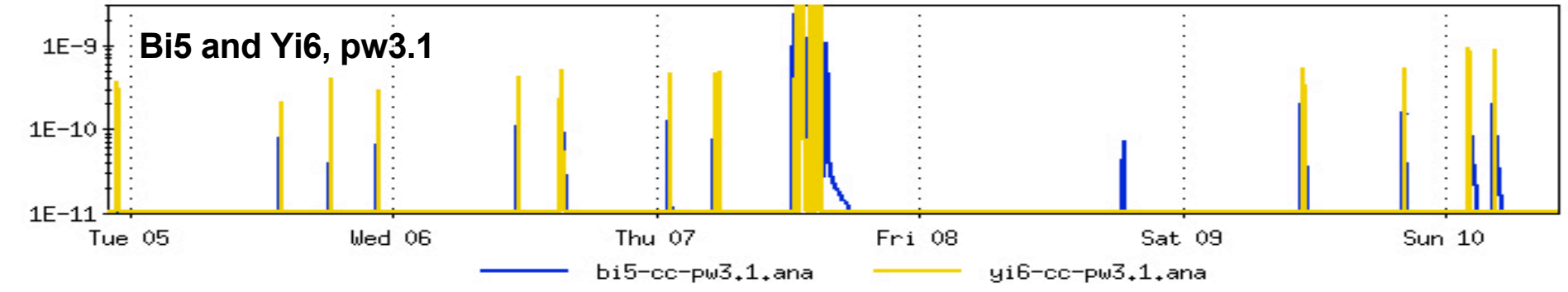


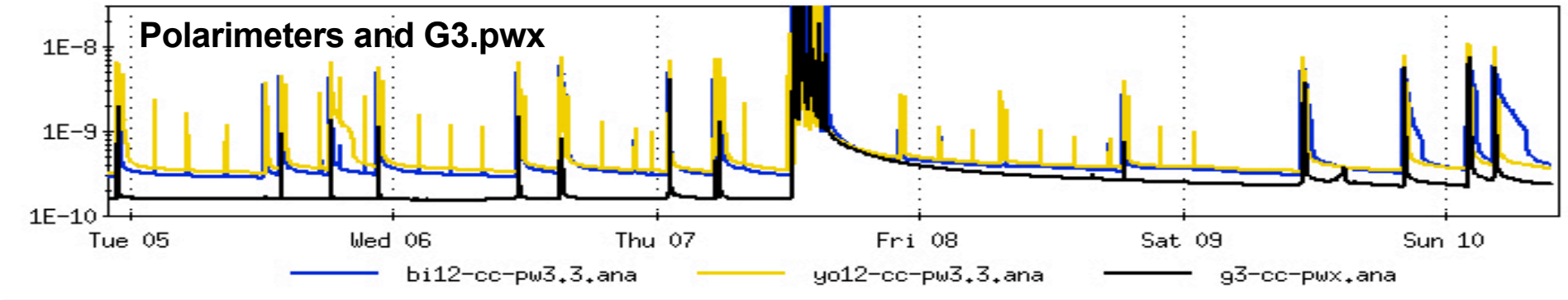


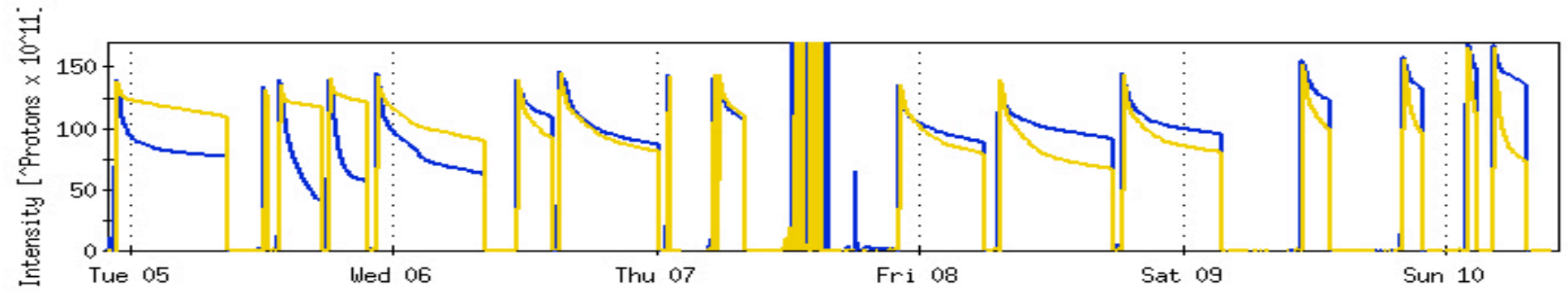
Yellow horizontal tune shift

3. Electron multipacting and tune shift.

- Electron multipacting signal at Bi1- pw3.1h and the bunch pattern, two gaps at ~ 40 bunches had large effect.
- Yellow horizontal tune shift along with the bunch train, seems to be ~ 0.002.
- More uniform bunch filling pattern may help better tune measurement.

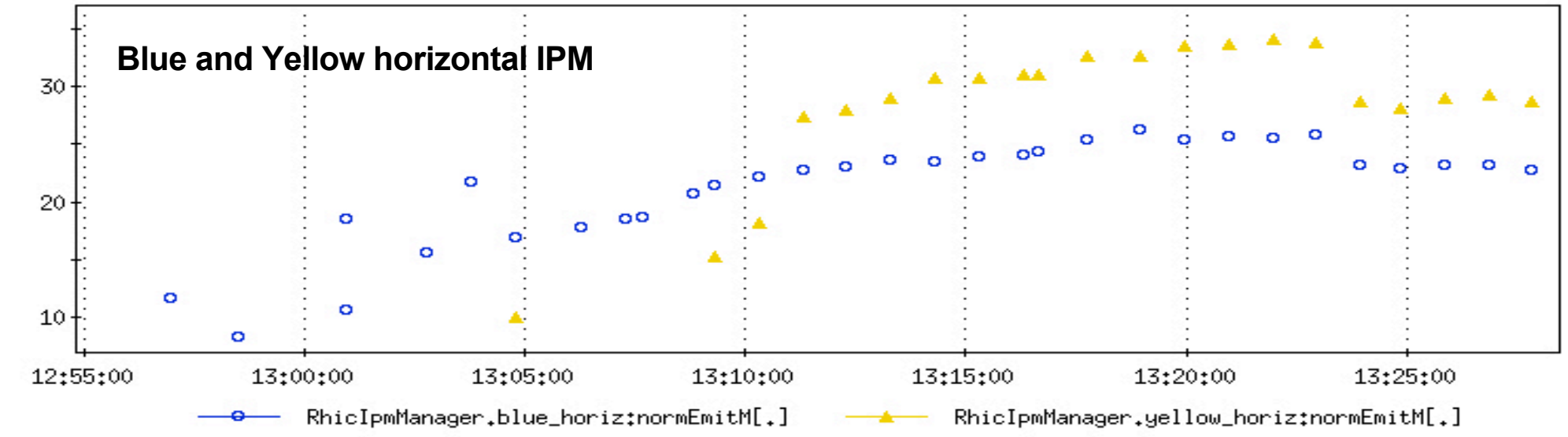


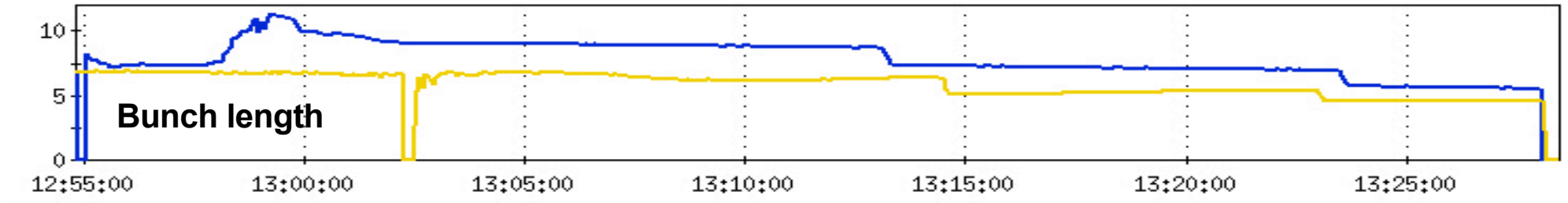


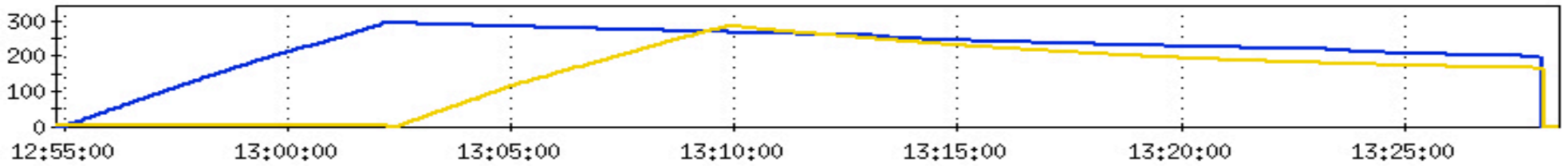


4. Scrubbing effect and memory

- **Most sections with high pressure rise had some improvement: with the same beam intensity the pressure rise is lower after the scrubbing run.**
- **Memory of the scrubbing seems to be weakened in ~ 2 days.**
- **So an intense scrubbing of ~ 2 hours could be used in the operations?**

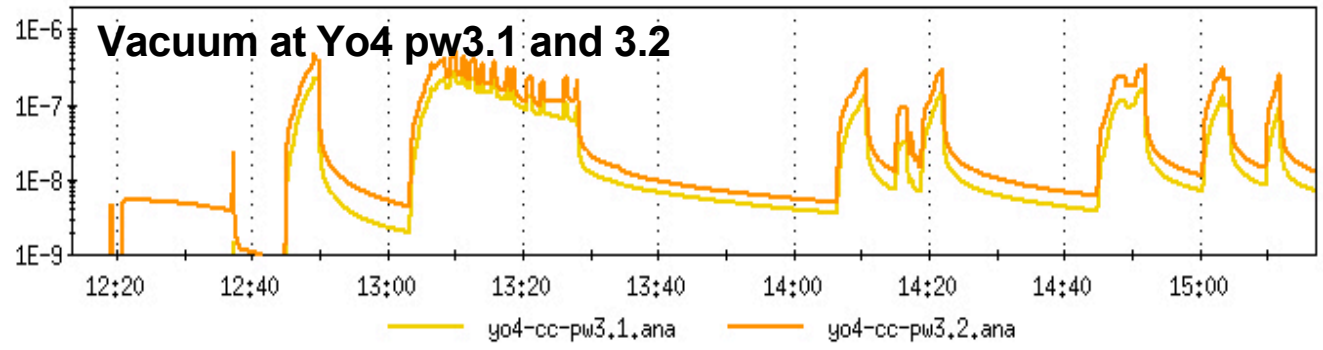


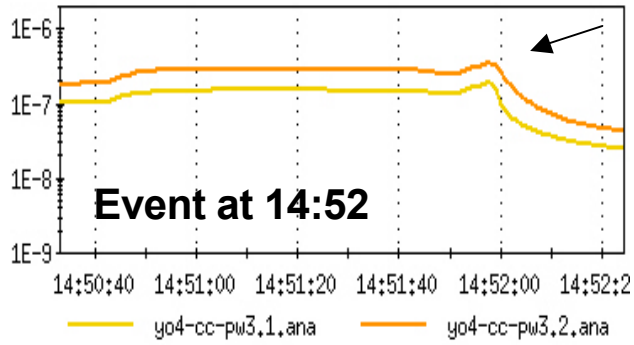


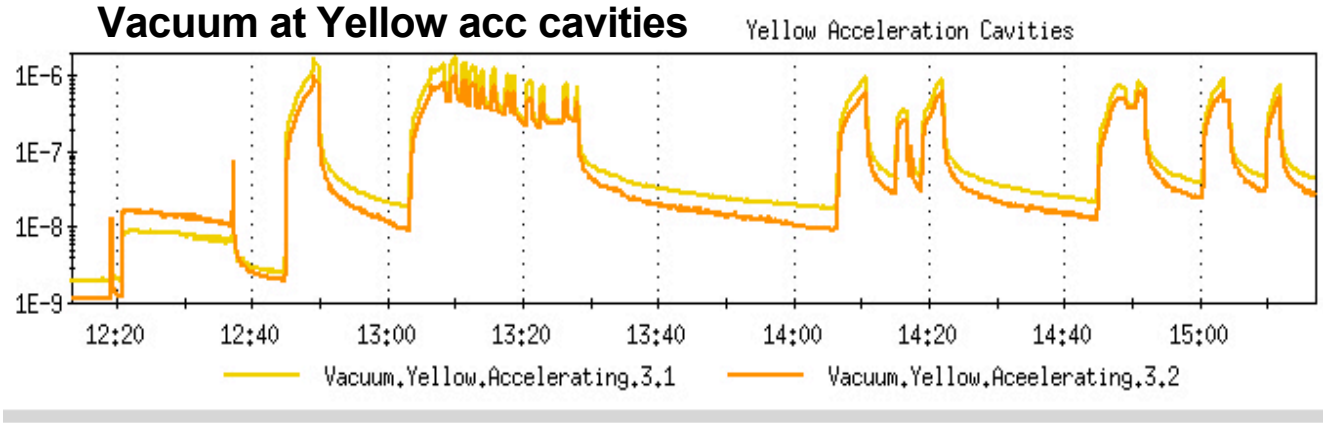


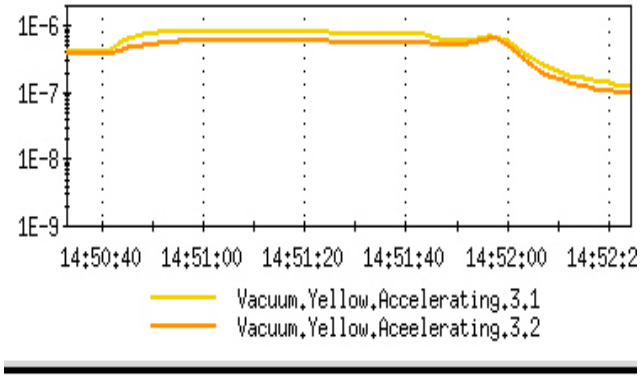
5. IPM observation and corrections

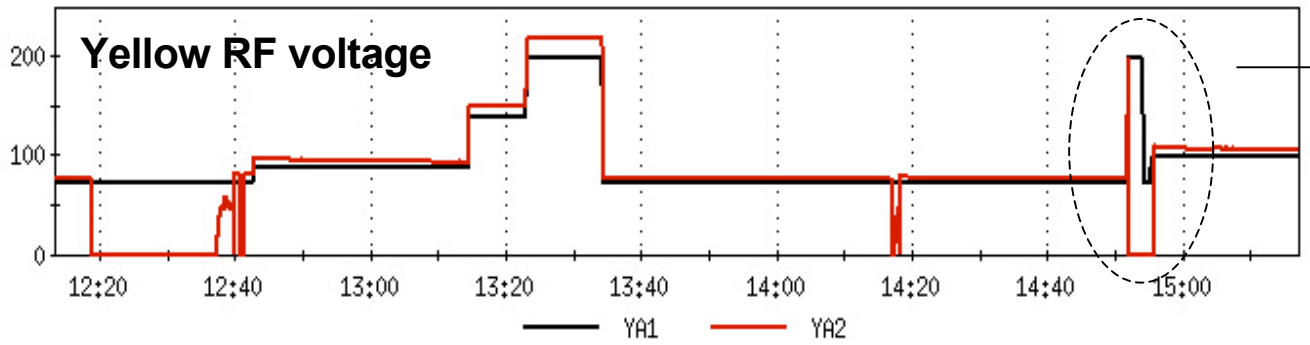
- **BH and YH emittance looks growing, average electron density in rings is ~ 1.9e10/ m³.**
- **IPM vacuum increased > 100 time to ~ 1e-7 Torr, to compensate the MCP bias is lowered, but met a limit. Most data can be considered valid. More study is needed.**
- **Shortly after this, the IPM tripped off due to pressure rise, and did not come back.**

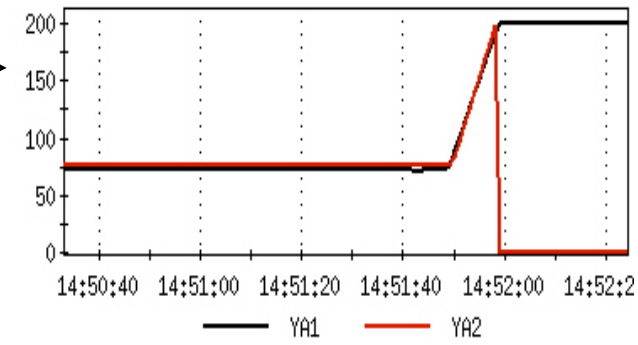






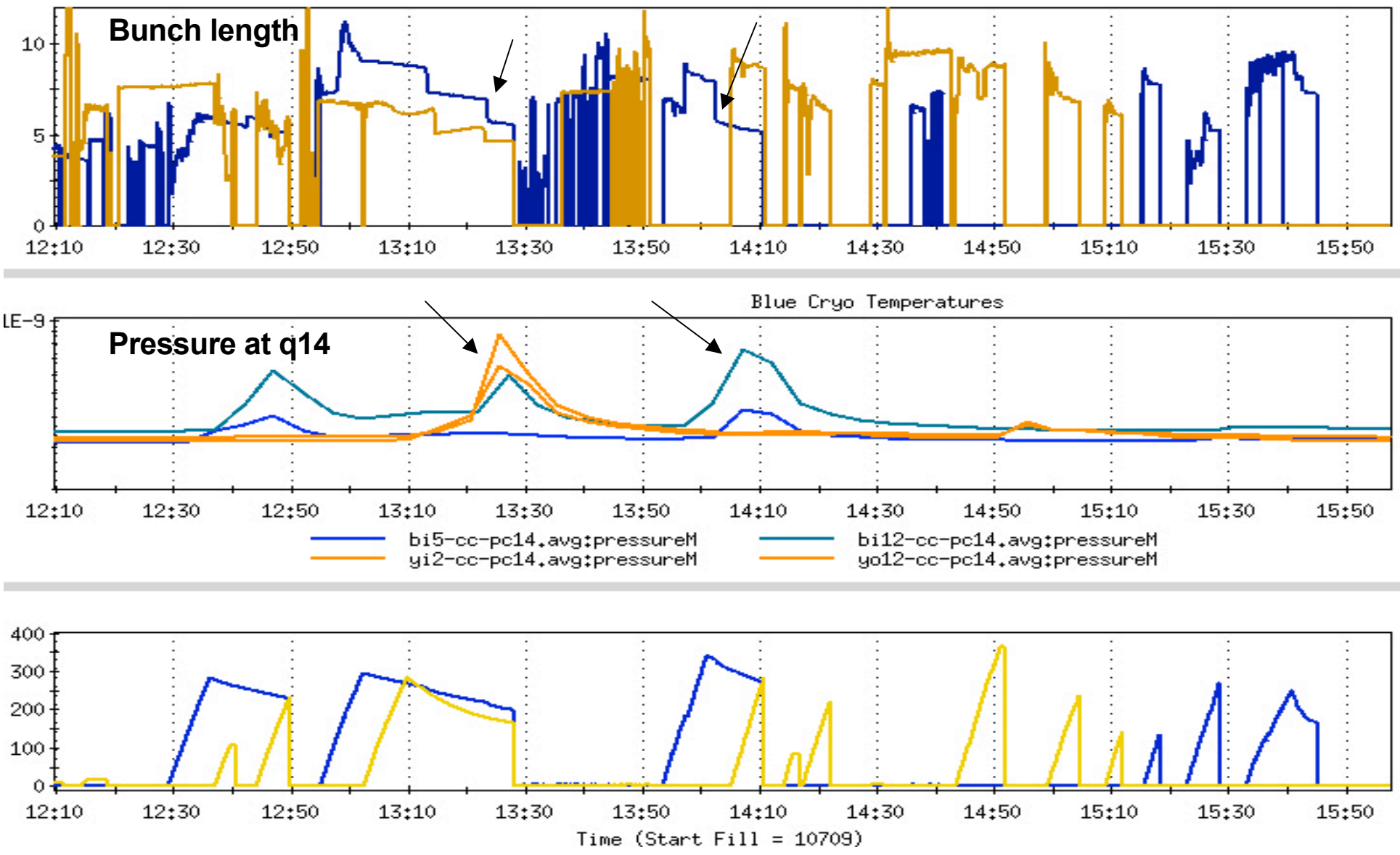






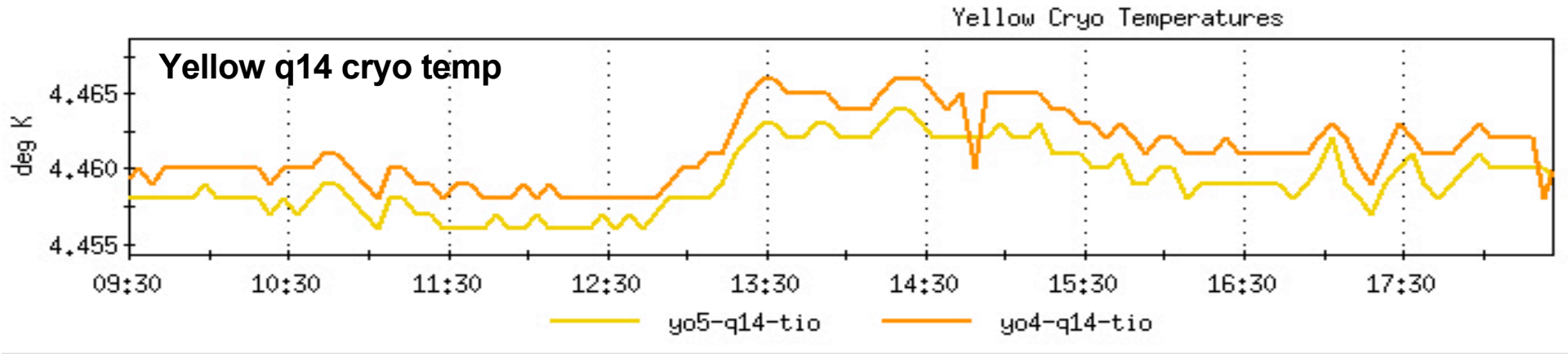
6. RF cavity trip-off, due to pressure rise?

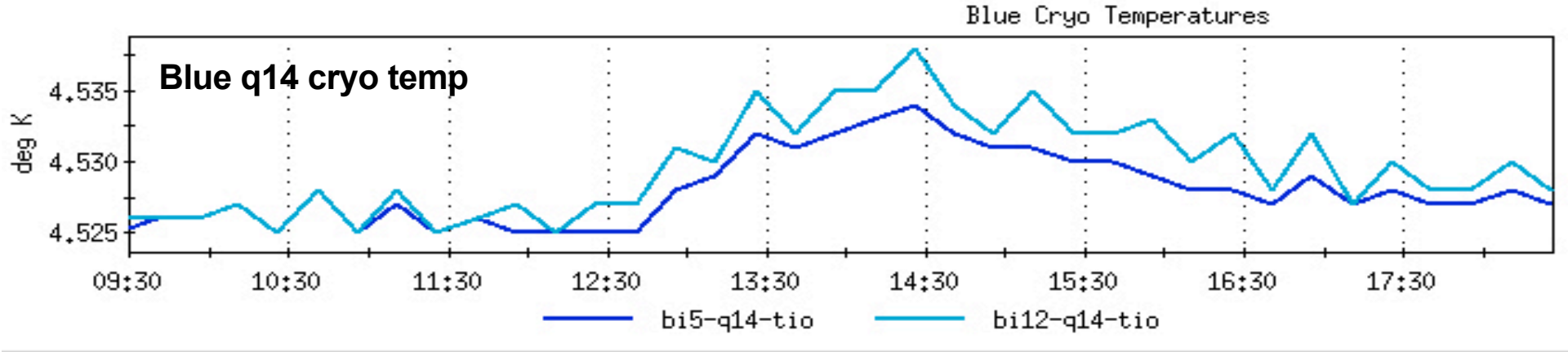
- **Accelerating cavity YA2 tripped several times, and the blow-up for the event at 14:52 shows that is due to the vacuum in the cavity.**
- **Pressure rise in Yellow cavities is 4 to 5 times higher than in Yo4-pw3.1 and pw3.2, noting that the cavities are located between these two gauges + pumps.**

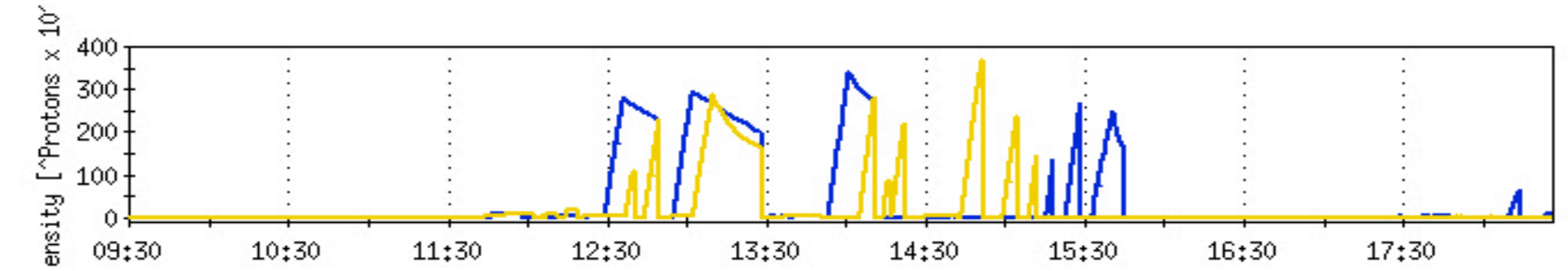


7. Cold region pressure rise

- Pressure rise at arcs are presented, here are some at q14s.
- These pressure rises take place with high intensity and also shorter bunches. It looks that the bunch length is a very important factor here.







8. Heat load

- **Heat load observed at Blue and Yellow arcs, here are some at q14s, 0.005 degree K? Similarly at dXs, and q21s are higher.**
- **Better logging is needed for analysis.**

Summary and conclusion

- With the 111-bunch proton beams at the RHIC injection, up to 4e11 protons per bunch, the electron multipacting, dynamic pressure rise, tune shift, transverse emittance growth, heat load, etc. are studied. The scrubbing effect is demonstrated, providing benefits for at least 2 days.
- At the total 350e11 to 400e11 protons in the RHIC rings, the electron cloud has affected the RF cavities (not clear why yet). The heat load is not at the limit yet, but might be an issue. The beam loss at the injection is OK, but we are very careful. In the scrubbing run 2005, many BPMs were damaged, this is fixed in 2009.
- For RHIC proton runs, since the AGS is able to provide 4e11 (unpolarized) protons per bunch or even higher, the scrubbing at the injection with a reasonable time, e.g. 2 hours, looks feasible. The key of efficient scrubbing is to keep the high pressure rise in the ring. We can use the AGS quad pumping and higher RF voltage to enhance the peak current. The scrubbing memory needs more studies.
- For RHIC heavy ion beams, the electron cloud is peaked at the transition, which causes beam instability, and therefore it is one of the ion beam intensity limit. A direct beam scrubbing is difficult, therefore, to use proton beam at the injection is proposed in a simulation study (P. He, M. Blaskiewicz, W. Fisher, PAC09). The short bunches could be achieved at the AGS extraction, and also to inject the beam close to the RHIC transition.